

# Broad-band Modelling of GRB Afterglows

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**Abstract.** Observations of GRB afterglows ranging from radio to X-ray frequencies generate large data sets. Careful analysis of these broad-band data can give us insight into the nature of the GRB progenitor population by yielding such information like the total energy of the burst, the geometry of the fireball and the type of environment into which the GRB explodes. We illustrate, by example, how global, self-consistent fits are a robust approach for characterizing the afterglow emission. This approach allows a relatively simple comparison of different models and a way to determine the strengths and weaknesses of these models, since all are treated self-consistently. Here we quantify the main differences between the broad-band, self-consistent approach and the traditional approach, using GRB 000301C and GRB 970508 as test cases.

## 1 Introduction

The quest for an understanding of GRB and afterglow physics, as well as the parameters that characterize the burst has recently led us to a new approach to the modelling of afterglow data. In principle, by modelling the afterglow data it is possible to extract the five parameters characterizing the synchrotron spectrum ( $\nu_a$ ,  $\nu_m$ ,  $\nu_c$ ,  $p$ , and  $F_{\nu_m}$ ) from which we can calculate the burst energy, the ambient medium density, and the fractions of energy in the magnetic fields and electrons [8]. At the same time, with accurate modelling it is possible to distinguish between the different models of afterglow emission, i.e. ISM vs. wind, and spherical vs. collimated outflow [1] [9] [7] [2] [3].

## 2 The Shortcomings of the Traditional Approach

Since the discovery of afterglow emission from GRBs in the late 1990s, the general approach to afterglow modelling has consisted of the following steps [10]. The data set collected for a particular burst was broken up into lightcurves and spectra, which were fitted separately. The spectra were modelled using the broken synchrotron spectrum in order to extract the value of  $p$ , and possibly the break frequencies. The lightcurves were each fitted separately to solve for the temporal decay slopes,  $\alpha_i$ , which were then compared for consistency, and in the optical band to extract any host galaxy extinction. The temporal decay slopes were also used to distinguish between the different models of afterglow emission, and breaks were used to infer the existence of a jet geometry. This approach has several serious drawbacks:

- Only a few data points are modelled at a time, and the uncertainty in the derived parameters is large.
- The deduced model parameters and power-law indices are not always physically meaningful (e.g. can give  $\epsilon_B > 1$ ).
- Since this approach employs the broken synchrotron power-law, the modelling of lightcurves and spectra near the break frequencies is inaccurate.
- It is extremely difficult to account for the changes in the spectrum and time dependences when the order of the break frequencies changes.

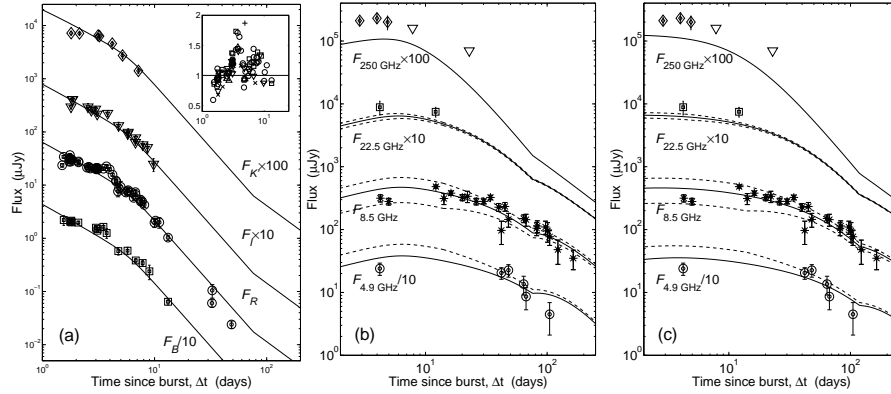
### 3 The Advantages of the Broad-band Approach

Our approach attempts to remedy the aforementioned problems, and in addition to clearly identify the present shortcomings of afterglow studies. The procedure we use in modelling the data is significantly different. We use a broad-band data set ranging from radio to X-rays and fit it simultaneously [1]. We therefore give equal weight to all data points, and do not disregard scattered data points, which in the traditional approach are useless. Our approach also tests a complete model with all its different early and late time variations, including the transition to the sub-relativistic phase. It is therefore self-consistent since it does not include or exclude any assumptions and constraints that are part of the complete model. With this approach we gain the following advantages:

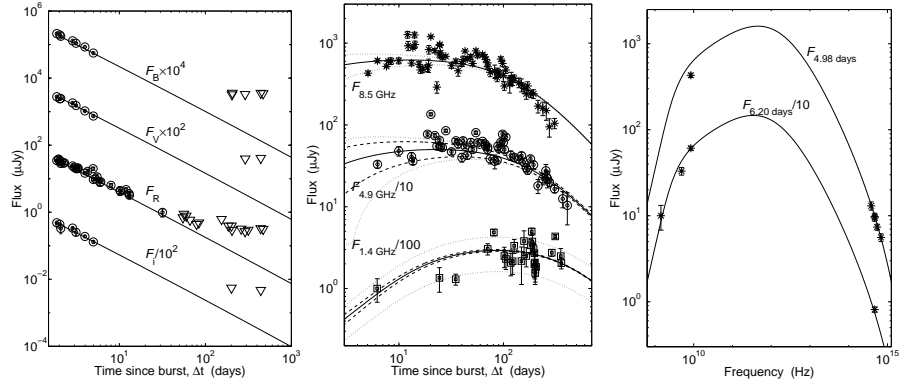
- All data points are used simultaneously since the model includes both the temporal and frequency dependence of each parameter.
- We use the Granot, Piran and Sari smoothed synchrotron spectrum [5] [6], which is a much more accurate and realistic representation of the actual data.
- We can easily include all special cases of the spectral and temporal evolution; therefore, any significant deviation of the data from the predicted models can be interpreted as a possibly new phenomenon (e.g. GRB 000301C [1] [4]).
- We can easily extract the values of the burst energy, ambient density and fractions of energy in the magnetic fields and electrons.
- We can directly determine which model (e.g. ISM vs. Wind) gives the most accurate description of the data using a simple  $\chi^2$  statistic.

### 4 Conclusion

The study of GRB afterglows and the extraction of the burst characteristics from the observations can be severely limited if a narrow-band approach is used. The problems of this traditional approach to modelling are numerous, but they can be easily solved if a broad-band, self-consistent approach is used instead. We have shown that the overall behavior of the afterglow emission can be easily studied within this approach, that the correct emission model can be unambiguously identified if the data set is large enough, and that the parameters characterizing the burst (e.g. energy, ambient density) can be easily solved for.



**Fig. 1.** (a) Optical and (b) radio lightcurves of GRB 000301C for the ISM+jet model and (c) the wind+jet model. The dashed lines indicate flux variation due to scintillation. The models include a jet break and a non-relativistic phase. The insert shows the achromatic bump which was only evident as a result of the global fitting [1].



**Fig. 2.** Optical and radio lightcurves and spectra of GRB 970508 for the wind model. The Modelling includes the effect of host galaxy extinction and host flux density. Upper limits in the optical indicate measurements in which the host galaxy flux dominates.

## References

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